# Monolithic Function Generator

## GENERAL DESCRIPTION

The XR-2206 is a monolithic function generator integrated circuit capable of producing high quality sine, square, triangle, ramp, and pulse waveforms of high-stability and accuracy. The output waveforms can be both amplitude and frequency modulated by an external voltage. Frequency of operation can be selected externally over a range of 0.01 Hz to more than 1 MHz.

The circuit is ideally suited for communications, instrumentation, and function generator applications requiring sinusoidal tone, AM, FM, or FSK generation. It has a typical drift specification of 20 ppm/°C. The oscillator frequency can be linearly swept over a 2000:1 frequency range, with an external control voltage, having a very small affect on distortion.

## FEATURES

| | |
|---|---|
| Low-Sine Wave Distortion | .5%, Typical |
| Excellent Temperature Stability | 20 ppm/°C, Typical |
| Wide Sweep Range | 2000:1, Typical |
| Low-Supply Sensitivity | 0.01%V, Typical |
| Linear Amplitude Modulation | |
| TTL Compatible FSK Controls | |
| Wide Supply Range | 10V to 26V |
| Adjustable Duty Cycle | 1% to 99% |

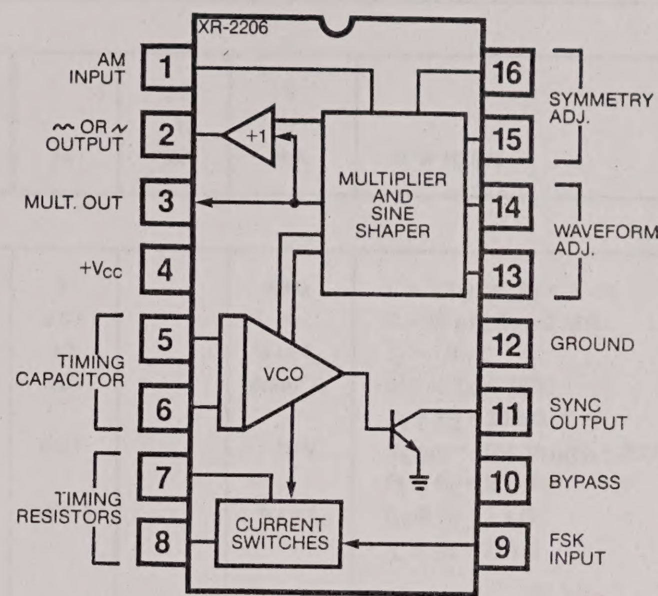
## APPLICATIONS

Waveform Generation
Sweep Generation
AM/FM Generation
V/F Conversion
FSK Generation
Phase-Locked Loops (VCO)

## ABSOLUTE MAXIMUM RATINGS

| | |
|---|---|
| Power Supply | 26V |
| Power Dissipation | 750 mW |
| Derate Above 25°C | 5 mW/°C |
| Total Timing Current | 6 mA |
| Storage Temperature | -65°C to +150°C |

## FUNCTIONAL BLOCK DIAGRAM




## ORDERING INFORMATION

| Part Number | Package | Operating Temperature |
|---|---|---|
| XR-2206M | Ceramic | -55°C to +125°C |
| XR-2206N | Ceramic | 0°C to +70°C |
| XR-2206P | Plastic | 0°C to +70°C |
| XR-2206CN | Ceramic | 0°C to +70°C |
| XR-2206CP | Plastic | 0°C to +70°C |

## SYSTEM DESCRIPTION

The XR-2206 is comprised of four functional blocks; a voltage-controlled oscillator (VCO), an analog multiplier and sine-shaper; a unity gain buffer amplifier; and a set of current switches.

The VCO actually produces an output frequency porportional to an input current, which is produced by a resistor from the timing terminals to ground. The current switches route one of the timing pins current to the VCO controlled by an FSK input pin, to produce an output frequency. With two timing pins, two discrete output frequencies can be independently produced for FSK Generation Applications.

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## ELECTRICAL CHARACTERISTICS

**Test Conditions:** Test Circuit of Figure 1, $V^+ = 12V$, $T_A = 25°$, $C = 0.01\ \mu F$, $R_1 = 100\ k\Omega$, $R_2 = 10\ k\Omega$, $R_3 = 25\ k\Omega$ unless otherwise specified. $S_1$ open for triangle, closed for sine wave.

| PARAMETER | XR-2206M | | | XR-2206C | | | UNIT | CONDITIONS |
|---|---|---|---|---|---|---|---|---|
| | MIN. | TYP. | MAX. | MIN. | TYP. | MAX. | | |
| GENERAL CHARACTERISTCS | | | | | | | | |
| Single Supply Voltage | 10 | | 26 | 10 | | 26 | V | |
| Split-Supply Voltage | ±5 | | ±13 | ±5 | | ±13 | V | |
| Supply Current | | 12 | 17 | | 14 | 20 | mA | $R_1 \geq 10\ k\Omega$ |
| OSCILLATOR SECTION | | | | | | | | |
| Max. Operating Frequency | 0.5 | 1 | | 0.5 | 1 | | MHz | $C = 1000\ pF$, $R_1 = 1\ k\Omega$ |
| Lowest Practical Frequency | | 0.01 | | | 0.01 | | Hz | $C = 50\ \mu F$, $R_1 = 2\ M\Omega$ |
| Frequency Accuracy | | ±1 | ±4 | | ±2 | | % of $f_o$ | $f_o = 1/R_1C$ |
| Temperature Stability | | ±10 | ±50 | | ±20 | | ppm/°C | $0°C \leq T_A \leq 75°C$, $R_1 = R_2 = 20\ k\Omega$ |
| Supply Sensitivity | | 0.01 | 0.1 | | 0.01 | | %/V | $V_{LOW} = 10V$, $V_{HIGH} = 20V$, $R_1 = R_2 = 20\ k\Omega$ |
| Sweep Range | 1000:1 | 2000:1 | | | 2000:1 | | $f_H = f_L$ | $f_H$ @ $R_1 = 1\ k\Omega$, $f_L$ @ $R_1 = 2\ M\Omega$ |
| Sweep Linearity | | | | | | | | |
| 10:1 Sweep | | 2 | | | 2 | | % | $f_L = 1\ kHz$, $f_H = 10\ kHz$ |
| 1000:1 Sweep | | 8 | | | 8 | | % | $f_L = 100\ Hz$, $f_H = 100\ kHz$ |
| FM Distortion | | 0.1 | | | 0.1 | | % | ±10% Deviation |
| Recommended Timing Components | | | | | | | | |
| Timing Capacitor: C | 0.001 | | 100 | 0.001 | | 100 | μF | See Figure 4. |
| Timing Resistors: $R_1$ & $R_2$ | 1 | | 2000 | 1 | | 2000 | kΩ | |
| Triangle Sine Wave Output | | | | | | | | See Note 1, Figure 2. |
| Triangle Amplitude | | 160 | | | 160 | | mV/kΩ | Figure 1, $S_1$ Open |
| Sine Wave Amplitude | 40 | 60 | 80 | | 60 | | mV/kΩ | Figure 1, $S_1$ Closed |
| Max. Output Swing | | 6 | | | 6 | | Vp-p | |
| Output Impedance | | 600 | | | 600 | | Ω | |
| Triangle Linearity | | 1 | | | 1 | | % | |
| Amplitude Stability | | 0.5 | | | 0.5 | | dB | For 1000:1 Sweep |
| Sine Wave Amplitude Stability | | 4800 | | | 4800 | | ppm/°C | See Note 2. |
| Sine Wave Distortion | | | | | | | | |
| Without Adjustment | | 2.5 | | | 2.5 | | % | $R_1 = 30\ k\Omega$ |
| With Adjustment | | 0.4 | 1.0 | | 0.5 | 1.5 | % | See Figures 6 and 7. |
| Amplitude Modulation | | | | | | | | |
| Input Impedance | 50 | 100 | | 50 | 100 | | kΩ | |
| Modulation Range | | 100 | | | 100 | | % | |
| Carrier Suppression | | 55 | | | 55 | | dB | |
| Linearity | | 2 | | | 2 | | % | For 95% modulation |
| Square-Wave Output | | | | | | | | |
| Amplitude | | 12 | | | 12 | | Vp-p | Measured at Pin 11. |
| Rise Time | | 250 | | | 250 | | nsec | $C_L = 10\ pF$ |
| Fall Time | | 50 | | | 50 | | nsec | $C_L = 10\ pF$ |
| Saturation Voltage | | 0.2 | 0.4 | | 0.2 | 0.6 | V | $I_L = 2\ mA$ |
| Leakage Current | | 0.1 | 20 | | 0.1 | 100 | μA | $V_{11} = 26V$ |
| FSK Keying Level (Pin 9) | 0.8 | 1.4 | 2.4 | 0.8 | 1.4 | 2.4 | V | See section on circuit controls |
| Reference Bypass Voltage | 2.9 | 3.1 | 3.3 | 2.5 | 3 | 3.5 | V | Measured at Pin 10. |

**Note 1:** Output amplitude is directly proportional to the resistance, R

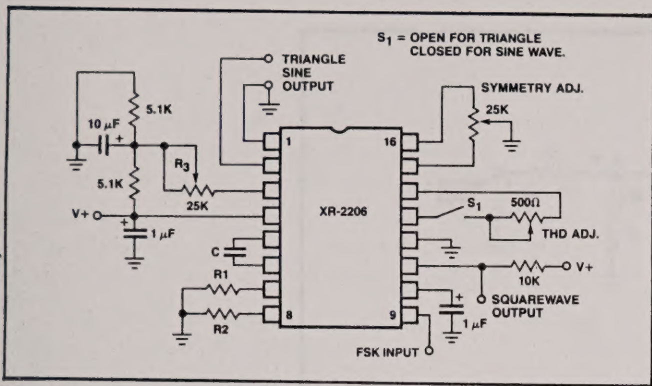


Figure 1: Basic Test Circuit.

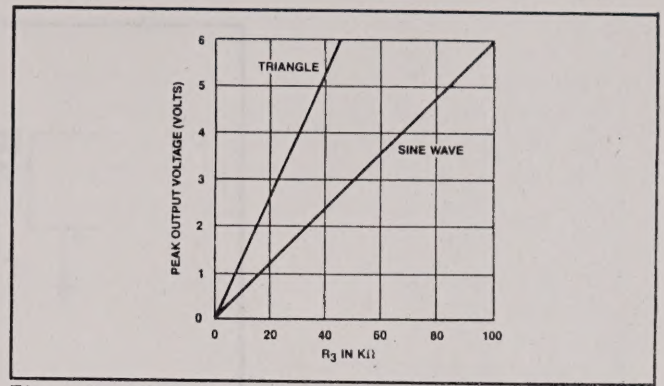


Figure 2: Output Amplitude as a Function of the Resistor, $R_3$, at Pin 3.

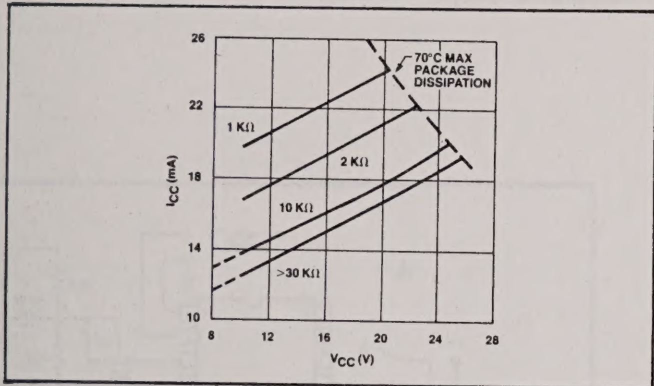


Figure 3: Supply Current versus Supply Voltage, Timing, R.

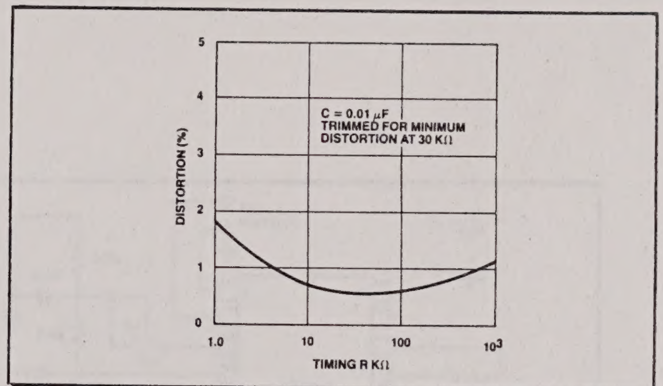


Figure 6: Trimmed Distortion versus Timing Resistor.

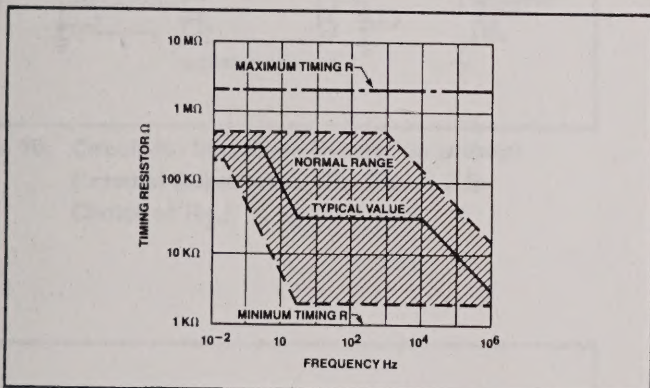


Figure 4: R versus Oscillation Frequency.

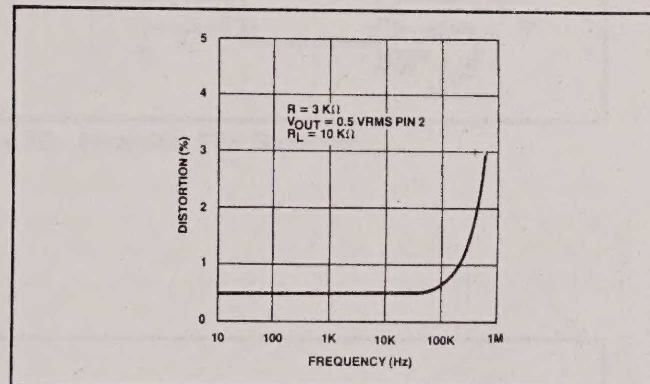


Figure 7: Sine Wave Distortion versus Operating Frequency with Timing Capacitors Varied.

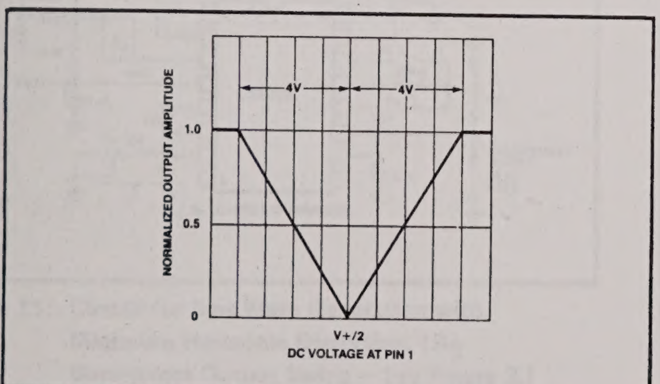


Figure 5: Normalized Output Amplitude versus DC Bias at AM Input (Pin 1).

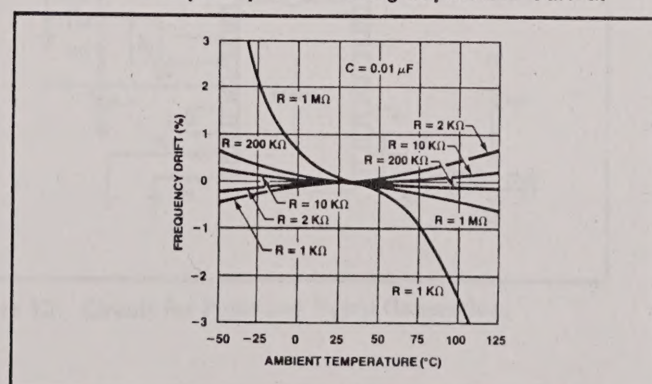


Figure 8: Frequency Drift versus Temperature.

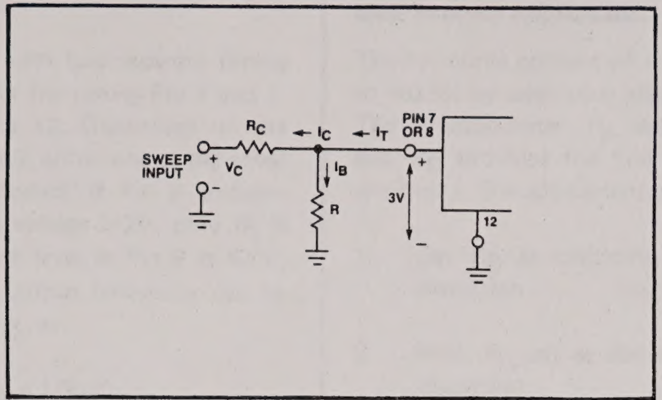


**Figure 9: Circuit Connection for Frequency Sweep.**

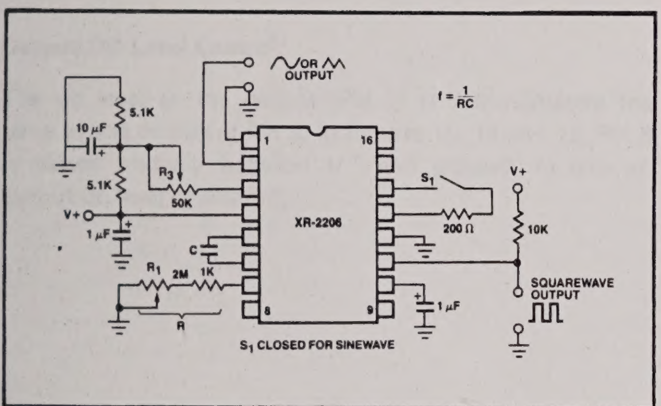


**Figure 10: Circuit for Sine Wave Generation without External Adjustment. (See Figure 2 for Choice of $R_3$.)**

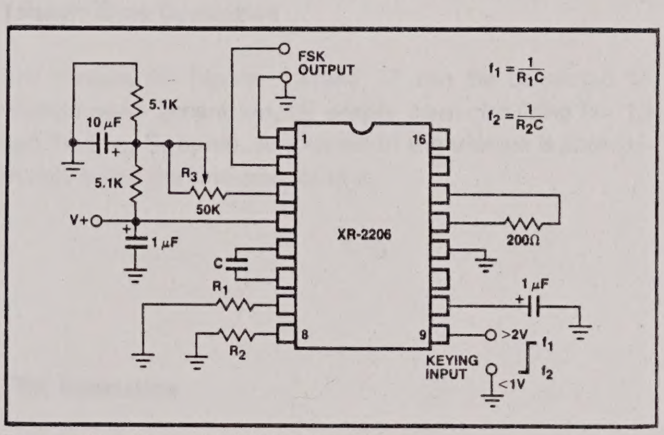


**Figure 12: Sinusoidal FSK Generator.**

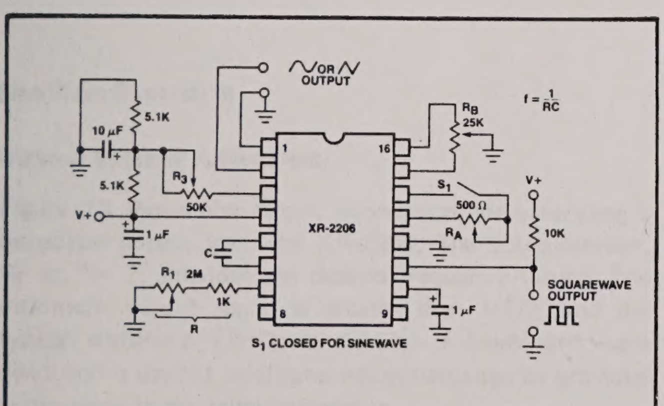


**Figure 11: Circuit for Sine Wave Generation with Minimum Harmonic Distortion. ($R_3$ Determines Output Swing — See Figure 2.)**

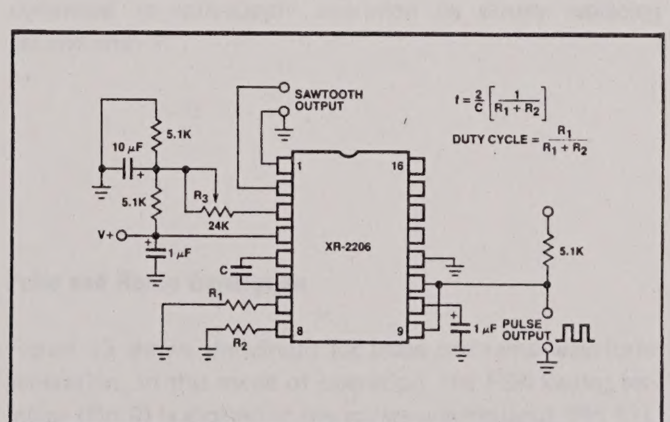


**Figure 13: Circuit for Pulse and Ramp Generation.**

**Frequency-Shift Keying:**

The XR-2206 can be operated with two separate timing resistors, $R_1$ and $R_2$, connected to the timing Pin 7 and 8, respectively, as shown in Figure 12. Depending on the polarity of the logic signal at Pin 9, either one or the other of these timing resistors is activated. If Pin 9 is open-circuited or connected to a bias voltage $\geqslant$2V, only $R_1$ is activated. Similarly, if the voltage level at Pin 9 is $\leqslant$1V, only $R_2$ is activated. Thus, the output frequency can be keyed between two levels, $f_1$ and $f_2$, as:

$$f_1 = 1/R_1C \text{ and } f_2 = 1/R_2C$$

For split-supply operation, the keying voltage at Pin 9 is referenced to $V^-$.

**Output DC Level Control:**

The dc level at the output (Pin 2) is approximately the same as the dc bias at Pin 3. In Figures 10, 11 and 12, Pin 3 is biased midway between $V^+$ and ground, to give an output dc level of $\approx V^+/2$.

## APPLICATIONS INFORMATION

### Sine Wave Generation

**Without External Adjustment:**

Figure 10 shows the circuit connection for generating a sinusoidal output from the XR-2206. The potentiometer, $R_1$ at Pin 7, provides the desired frequency tuning. The maximum output swing is greater than $V^+/2$, and the typical distortion (THD) is <2.5%. If lower sine wave distortion is desired, additional adjustments can be provided as described in the following section.

The circuit of Figure 10 can be converted to split-supply operation, simply by replacing all ground connections with $V^-$. For split-supply operation, $R_3$ can be directly connected to ground.

**With External Adjustment:**

The harmonic content of sinusoidal output can be reduced to $\approx$0.5% by additional adjustments as shown in Figure 11. The potentiometer, $R_A$, adjusts the sine-shaping resistor, and $R_B$ provides the fine adjustment for the waveform symmetry. The adjustment procedure is as follows:

1. Set $R_B$ at midpoint, and adjust $R_A$ for minimum distortion.
2. With $R_A$ set as above, adjust $R_B$ to further reduce distortion.

### Triangle Wave Generation

The circuits of Figures 10 and 11 can be converted to triangle wave generation, by simply open-circuiting Pin 13 and 14 (i.e., $S_1$ open). Amplitude of the triangle is approximately twice the sine wave output.

### FSK Generation

Figure 12 shows the circuit connection for sinusoidal FSK signal operation. Mark and space frequencies can be independently adjusted, by the choice of timing resistors, $R_1$ and $R_2$; the output is phase-continuous during transitions. The keying signal is applied to Pin 9. The circuit can be converted to split-supply operation by simply replacing ground with $V^-$.

### Pulse and Ramp Generation

Figure 13 shows the circuit for pulse and ramp waveform generation. In this mode of operation, the FSK keying terminal (Pin 9) is shorted to the square-wave output (Pin 11), and the circuit automatically frequency-shift keys itself between two separate frequencies during the positive-going and negative-going output waveforms. The pulse width and duty cycle can be adjusted from 1% to 99%, by the choice of $R_1$ and $R_2$. The values of $R_1$ and $R_2$ should be in the range of 1 k$\Omega$ to 2 M$\Omega$.

**Frequency-Shift Keying:**

The XR-2206 can be operated with two separate timing resistors, $R_1$ and $R_2$, connected to the timing Pin 7 and 8, respectively, as shown in Figure 12. Depending on the polarity of the logic signal at Pin 9, either one or the other of these timing resistors is activated. If Pin 9 is open-circuited or connected to a bias voltage $\geq 2V$, only $R_1$ is activated. Similarly, if the voltage level at Pin 9 is $\leq 1V$, only $R_2$ is activated. Thus, the output frequency can be keyed between two levels, $f_1$ and $f_2$, as:

$$f_1 = 1/R_1C \text{ and } f_2 = 1/R_2C$$

For split-supply operation, the keying voltage at Pin 9 is referenced to $V^-$.

**Output DC Level Control:**

The dc level at the output (Pin 2) is approximately the same as the dc bias at Pin 3. In Figures 10, 11 and 12, Pin 3 is biased midway between $V^+$ and ground, to give an output dc level of $\approx V^+/2$.

## APPLICATIONS INFORMATION

**Sine Wave Generation**

**Without External Adjustment:**

Figure 10 shows the circuit connection for generating a sinusoidal output from the XR-2206. The potentiometer, $R_1$ at Pin 7, provides the desired frequency tuning. The maximum output swing is greater than $V^+/2$, and the typical distortion (THD) is < 2.5%. If lower sine wave distortion is desired, additional adjustments can be provided as described in the following section.

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The harmonic content of sinusoidal output can be reduced to $\approx 0.5\%$ by additional adjustments as shown in Figure 11. The potentiometer, $R_A$, adjusts the sine-shaping resistor, and $R_B$ provides the fine adjustment for the waveform symmetry. The adjustment procedure is as follows:

1. Set $R_B$ at midpoint, and adjust $R_A$ for minimum distortion.

2. With $R_A$ set as above, adjust $R_B$ to further reduce distortion.

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The circuits of Figures 10 and 11 can be converted to triangle-wave generation, by simply open-circuiting Pin 13 and 14 (i.e., $S_1$ open). Amplitude of the triangle is approximately twice the sine wave output.

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Figure 12 shows the circuit connection for sinusoidal FSK signal generation. Mark and space frequencies can be independently adjusted, by the choice of timing resistors, $R_1$ and $R_2$; the output is phase-continuous during transitions. The keying signal is applied to Pin 9. The circuit can be converted to split-supply operation by simply replacing ground with $V^-$.

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Figure 13 shows the circuit for pulse and ramp waveform generation. In this mode of operation, the FSK keying terminal (Pin 9) is shorted to the square-wave output (Pin 11), and the circuit automatically frequency-shift keys itself between two separate frequencies during the positive-going and negative-going output waveforms. The pulse width and duty cycle can be adjusted from 1% to 99% by the choice of $R_1$ and $R_2$. The values of $R_1$ and $R_2$ should be in the range of 1 kΩ to 2 MΩ.

## PRINCIPLES OF OPERATION

### Description of Controls

**Frequency of Operation:**
The frequency of oscillation, $f_o$, is determined by the external timing capacitor, C, across Pin 5 and 6, and by the timing resistor, R, connected to either Pin 7 or 8. The frequency is given as:

$$f_o = \frac{1}{RC}\ \text{Hz}$$

and can be adjusted by varying either R or C. The recommended values of R, for a given frequency range, are shown in Figure 4. Temperature stability is optimum for $4\ k\Omega < R < 200\ k\Omega$. Recommended values of C are from 1000 pF to 100 $\mu$F.

**Frequency Sweep and Modulation:**
Frequency of oscillation is proportional to the total timing current, $I_T$, drawn from Pin 7 or 8:

$$f = \frac{320 I_T\ (\text{mA})}{C\ (\mu\text{F})}\ \text{Hz}$$

Timing terminals (Pin 7 or 8) are low-impedance points, and are internally biased at +3V, with respect to Pin 12. Frequency varies linearly with $I_T$, over a wide range of current values, from 1 $\mu$A to 3 mA. The frequency can be controlled by applying a control voltage, $V_C$, to the activated timing pin as shown in Figure 9. The frequency of oscillation is related to $V_C$ as:

$$f = \frac{1}{RC}\ 1 + \frac{R}{R_C}\left(1 - \frac{V_C}{3}\right)\quad \text{Hz}$$

where $V_C$ is in volts. The voltage-to-frequency conversion gain, K, is given as:

$$K = \partial f/\partial V_C = -\frac{0.32}{R_C C}\ \text{Hz/V}$$

*CAUTION:* For safe operation of the circuit, $I_T$ should be limited to $\leqslant$3 mA.

**Output Amplitude:**
Maximum output amplitude is inversely proportional to the external resistor, $R_3$, connected to Pin 3 (see Figure 2). For sine wave output, amplitude is approximately 60 mV peak per k$\Omega$ of $R_3$; for triangle, the peak amplitude is approximately 160 mV peak per k$\Omega$ of $R_3$. Thus, for example, $R_3$ = 50 k$\Omega$ would produce approximately ±3V sinusoidal output amplitude.

**Amplitude Modulation:**
Output amplitude can be modulated by applying a dc bias and a modulating signal to Pin 1. The internal impedance at Pin 1 is approximately 100 k$\Omega$. Output amplitude varies linearly with the applied voltage at Pin 1, for values of dc bias at this pin, within ±4 volts of $V^+/2$ as shown in Figure 5. As this bias level approaches $V^+/2$, the phase of the output signal is reversed, and the amplitude goes through zero. This property is suitable for phase-shift keying and suppressed-carrier AM generation. Total dynamic range of amplitude modulation is approximately 55 dB.

*CAUTION:* AM control must be used in conjunction with a well-regulated supply, since the output amplitude now becomes a function of $V^+$.

**EQUIVALENT SCHEMATIC DIAGRAM**